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COMMITTEE ON SLAUGHTERING METHODS

appointed by the Danish Academy of Technical Sciences at the request of the Ministry of Justice

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SUMMARY.

The report contains in a summarizing form the committee's investigations on the effect of electric stunning on the quality of pork, particularly whether electric stunning could cause hemorrhages in the ham, loin and belly and in general more perishable meat.

It is shown that deleterious punctate hemorrhages in the muscles can be avoided if the time interval between the interruption of current flow and sticking is reduced to about 5 sec. Organoleptic and chemical investigations showed no difference in the perishability of the meat from stunned and unstunned hogs. The pH in macerate of m. gracilis from hams from unstunned and stunned hogs was the same.

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On February 16, 1955, the Ministry of Justice addressed itself to the Academy of Technical Science and inquired whether the Academy would be willing to investigate the effect of electric stunning on the quality of pork, particularly whether it could cause hemorrhages in the ham, loin and belly; less complete exsanguination; increased muscle rigidity or more perishable meat, specifically by causing an increase in its pH.

The Academy informed the Ministry of Justice on April 18, 1955, that the Academy was prepared to appoint a committee to investigate whether there was any basis for assuming that electric stunning resulted in a deterioration in the quality of pork of the nature mentioned in the Ministry of Justice's request.

The committee was named the COMMITTEE ON SLAUGHTERING METHODS and its members were:

Dr. H. Jørgensen, Professor of Technical biochemistry at the Royal Danish Technical University (Chairman). Dr. F. Buchthal, Professor of Neurophysiology at the University of Copenhagen. Dr. H. Fredholm, Director of the Laboratory of the Union of Meat Packers of Sweden, Stockholm. Aa. Jepsen, Professor of Veterinary Bacteriology and Hygiene at the Royal Danish Veterinary and Agricultural College. H.H. Johansen, Veterinary Inspector at the Cooperative Meat Packing Plant of Jutland (JAKA), Brabrand. M. Jul, Director of the Danish Meat Research Institute, Roskilde. Dr. R.E.H. Rasmussen, Professor of Technical Physics at the Royal Danish Technical University. The Committee's technical secretary was:

Dr. O. Sten-Knudsen, The Institute of Neurophysiology, University of Copenhagen.

The Committee held its organizational meeting on March 23, 1955 and held 12 meetings in all. In addition, various members of the Committee, during and in connection with the experiments, held detailed discussions on the problems which arose in connection with the Committee's experiments.

The following instituions and establishments assisted the Committee in the experiments:

The Danish Bacon Control, Sorø. The Royal Danish Technical University's Department of Technical Biochemistry, Copenhagen. The Hygienic-Bacteriological Laboratory, Royal Agricultural College Laboratory for Technical Physics, Royal Technical University. The Danish Meat Research Institute, Roskilde. The Neurophysiological Institute, Copenhagen, University of Copenhagen. The Pathological Anatomical Institute, Copenhagen, University of Copenhagen. Det Danske Kølehus "Cold Stores" Ltd. Copenhagen. Holbæk Cooperative Slaughterhouse, Holbæk. Kalundborg Cooperative Slaughterhouse, Kalundborg. Plumrose Ltd. Copenhagen. Sorø Cooperative Slaughterhouse, Sorø.

The Committee's investigation covered: 1272 slaughtered hogs, of which 483 were not and 789 were stunned electrically before slaughter. In addition, 1216 hams (608 hogs) were inspected while they were being cut up.

At a meeting on March 22, 1956, the members of the Committee unanimously endorsed the wording of a preliminary report sent out on March 26, 1956, and at a meeting on October 12, 1957 approved - also unanimously - the final report presented here:

Fritz Buchthal	Mogens Jul
Hugo Fredholm	Holger Jørgensen (Chairman)
Aage Jepsen	R.E.H. Rasmussen
H.H. Johansen	/ Ove Sten-Knudsen

THE COMMITTEE'S EXPERIMENTS

After its first meetings, it was clear to the Committee that the available information concerning the extent and significance of the damage mentioned by the Ministry was based on conflicting and unsatisfactory experimental data. The Committee decided therefore to undertake a series of investigations on hogs slaughtered with and without electric stunning, to establish the degree and type of injury. Furthermore an attempt was made to acquire knowledge of the physiological events during electric stunning which might contribute to or cause certain of the above-mentioned traumata with the end in view to devising an improved method of electric stunning.

The following investigations were carried out:

A technical examination of the different types of stunning apparatus. An investigation of the type and frequency of occurrence of intramuscular hemorrhage incident to slaughter. An investigation of the frequency of occurrence of pulmonary hemorrhage incident to slaughter. An investigation of the perishability of fresh hog carcasses in conjunction with pH measurements of the flesh.

A brief account follows of the results of the above-mentioned investigations and of the conclusions which the Committee has been able to draw from them. In addition, reference is made to any of the Committee's considerations which bear directly on the conclusions.

ELECTRIC STUNNING: TECHNIQUE AND PHYSIOLOGICAL MECHANISM

Stunning technique:

Electric stunning is effected by passing a suitable electric current across the hog's head. The current which traverses the hog's brain renders the animal unconscious for a period the duration of which depends on the stunning method. The current is applied through so-called stunning tongs. These may be shaped like metal tongs about 3/4 meters long; on each of the jaws is an electrode, insulated from the rest of the frame. The electrodes are connected to an appropriate current source (converter or transformer) during the entire slaughtering period and the current flows at the moment the electrodes come in contact with the hog's head. At the beginning of the stunning process, the electrodes are placed on the head of the hog behind the

ears; later in the stunning phase, the tongs are rotated so that one of the electrodes rests above one of the animal's eyes thus sending more of the total current through the hog's brain. It is essential for the success of the stunning procedure that the tongs be constructed to ensure prompt and close contact between electrodes and hog's head. A pair of Siemens two-hand tongs was used in the Committee's experiments in Sorø; these differ only slightly from other existing two-hand tongs.

In the Committee's first experimental series, the electric stunning technique was that which has been in use for a number of years at the Sorø Cooperative Slaughterhouse (referred to below as the routine method). This technique is as follows: 85 volts of alternating current were applied across the electrodes of the stunning tongs. (Between applications the electrodes were dipped frequently in salt water). The stunning current was applied for about 8 seconds on the average or until a certain degree of relaxation of the animal was obtained. After the tongs were removed, the animal was shackled to and raised on the sticking hoist and stock. Since the average time between the removal of the tongs and sticking was about 50 seconds, sticking was accomplished at the end of the clonic phase or in the beginning of the comatose stage (see the section on the physiological mechanism of electric stunning, page 6).

In view of the circulatory changes which occur in hogs during and after electric stunning, the Committee considered it possible to reduce or eliminate muscle hemorrhages incident to stunning by altering the stunning and slaughtering technique to the end that sticking be accomplished as soon as possible after termination of electrical stunning. Information gained from a visit to the SCAN slaughterhouse, Ängelholm, Sweden, also pointed in this direction as did written information from the chief veterinary officer, D.J. Anthony, M.R.C.V.S. (messrs. Marsh and Baxter Ltd., Brierly Hill, Staffs, England). The altered electric stunning technique was therefore tried in the Committee's later experimental series. This method is referred to as the short interval method in the tables of the report. The technique was that the stunner held the tongs on the animal's head before and during shackling and the animal was stuck immediately after removal of the tongs. With this method, the passage of the current lasted on an average to 10 seconds and the interval between removal of the tongs and sticking was, on the average, 5 seconds. Thus, the animal was stuck before onset of the clonic phase (see the section on the physiological action mechanism of electrical stunning page 6).

Technical examination of the apparatus used heretofore:

From a study of the available information, it became clear to the Committee at an early point that the extent of the damage attributed to electric stunning was estimated differently by different slaughterhouses. Since the various slaughterhouses use different equipment to carry out electric stunning, the Committee considered it necessary to examine the various types of stunning equipment in detail. The examination covered the following equipment: (1) a converter (Kemp and Lauritzen) (2) a transformer (Lübcke) (3) a stunning apparatus (Elther, not used in Denmark) (4) stunning tongs (Siemens "sharp electrodes") (5) stunning tongs (Siemens no. S. 36 "meat hammer electrodes"). The examination involved: Insulation measurements, recording of the current and voltage characteristics of the converter and transformer, determination of the current leakage to ground from the converter and the transformer and, in the case of the Elther apparatus, a check of the meter readings. The insulation measurements showed that all the insulation resistances were satisfactory for the converter, transformer and tongs as long as they were dry (20 - 50 MΩ). After dipping the electrodes in salt water - which is normal practice in using the tongs - the insulation resistance, that is, the resistance between the electrodes and the frame of the tongs, was unsatisfactorily low, often only 30 - 100 ohm. As a consequence the frame of the stunning tongs conducted current during use, deminishing the current flow through the animal.

The reamaining electrical measurements showed no significant difference between the various apparatus and need not be mentioned.

In view of the high humidity in the slaughterhouses, it can be said in summary, that the investigations showed that all of the apparatus, even though the are approved, are poorly constructed in principle. They offer a risk to the stunner, especially if the insulation in the transformer should fail, as well as wasting current.

The Committee would like to point out the danger that could be associated with using a transformer which has been in a damp place for a long time.

The Committee sugests that the Ministry of Justice call the attention of the Electricity Commission to the results of the Committee's investigations of the equipment heretofore used so that it may take up the question for renewed consideration.

The Committee has designed stunning tongs without the above-mentioned faults. The tongs were tested in practice and proved to be satisfactory, especially with regard to their insulation resistance.

Physiological Mechanism of Electric Stunning.

Unconsciousness during electric stunning corresponds to the condition during an epileptic fit and during electric shock treatments in humans. The basis of the stunning effect is probably a stimulation of nerve cells over a large area of the cortex and in deeper parts of the brain. This mass activation manifests itself by, among other things, a contraction of all muscles (including muscles of the eye). Preceding this convulsive activity there are three phases. An initial brief phase is characterized by paralysis of all muscles so that the hog can not maintain its normal position. Then the so-called tonic phase appears less than one second after the beginning of current flow; it is evidenced by sustained contraction of flexor and of extensor muscles. Since the latter are the strongest, this phase of electrical stunning manifests itself by an extension of the hog's front and hind legs. The tonic phase lasts for about 10 seconds after the current has ceased. Following the tonic phase is a brief period of 1 - 2 seconds when there is some degree of relaxation of the muscles. After this there follows the so-called clonic phase which consists of jerky, nearly rhythmic contractions such as walking-like movements of the fore and hind legs. This phase lasts about 30 - 45 seconds. After the clonic phase ensues a period of generalized object muscle paralysis, the so-called comatose stage, after which the animal awakens.

The question has been raised as to whether there really is unconsciousness with electric stunning or whether the muscles are paralyzed while the animal retains full consciousness. That during and after electric shock hogs do not feel pain can be judged from the animal's general reactions and from reports of persons who have been given electric shock. With regard to the animal's reaction during electric stunning, there is no doubt that it does not respond to external stimuli, that is, it seems to be unconscious. A more objective way of testing whether an animal is unconscious consists of investigating whether an involuntary movement of the eyelids can be evoked by touching the cornea of the eye, as invariably occurs under normal conditions (corneal reflex). The corneal reflex is absent as early as it has been possible to test for it (that is, immediately after the tongs are removed from the animal's head) and remains so for 1/2 to several minutes after

about 8 seconds' exposure to electric current. The absence of the corneal reflex indicates deep narcosis in anesthetized humans. It can therefore be concluded that the animal is unconscious from the beginning of electric stunning until sticking.

MUSCLE AND LUNG HEMORRHAGES.

A series of experiments was planned to allow a statistical evaluation of the frequency and nature of hemorrhages which appear in the muscles and lungs during slaughtering, both in unstunned hogs and in hogs stunned electrically by various techniques.

Muscle Hemorrhages

Punctate Hemorrhages in the Muscle

Bleeding in the flesh of slaughtered hogs may be punctate and patchy. The so-called punctate hemorrhages are pinhead-to pea-sized, usually slightly oval, dark bloody discolorations in the flesh. They are seen especially in ham, belly and loin (back muscles) as illustrated in the colour picture on page 9 . A very few may be restricted to a small area or they may be scattered copiously over large areas of the carcass. A microscopic examination of a number of muscle sections from stunned hogs with punctate homorrhages revealed that the bleeding was due to the rupture of congested capillaries.

To determine the incidence of punctate hemorrhages in the flesh of hogs slaughtered unstunned and stunned electrically by various techniques, the Committee investigated several series of hogs slaughtered at the Sorø Cooperative Slaughterhouse. The accessible muscle surfaces on ham, loin, and belly of the hog carcasses split down the back (split carcasses) were examined immediately after slaughter.

The main results appear in table I.

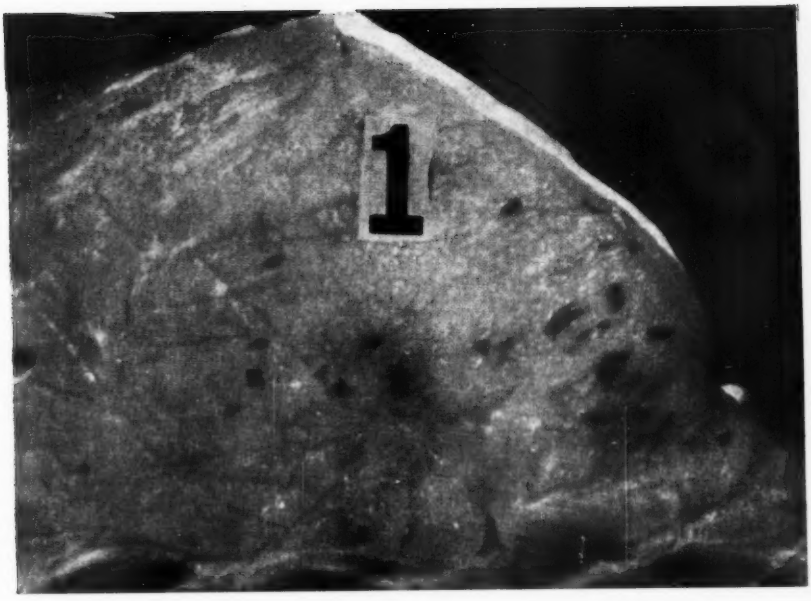
Table I: Deleterious punctate hemorrhages in the muscles of split hog carasses

	Electrically stunned		Unstunned
	routine method	short interval method	
Number of hogs	385	256	196
Number of hogs with deleterious punctate hemorrhages	3. (0.8 %)	0	0

Table II: Deleterious punctate hemorrhages in the muscles of cut up hams

	Electrically stunned		Unstunned
	routine method	short interval method	
Number of hams	79	543	485
Number of hams with deleterious punctate hemorrhages	4(5.1 %)	0	0

In another series of hogs slaughtered at the Sorø Slaughterhouse a close examination was made of the hams cut off the carcasses for the purpose of deboning and preparing them for canning at A/S Plumrose's canning plant in Copenhagen. For deboning, every ham is cut up into 4 or 5 pieces. This procedure allowed a detailed examination of the ham since each single piece could be examined on all sides. The punctate homorrhages were counted; more than 10 in each cut up ham was considered to be deleterious. The main results are shown in table II.



Example of multiple punctate hemorrhages
(3rd degree) in a ham.

The Committee also recorded the punctate hemorrhages considered insufficient in number to impair the quality of the meat. For the sake of completeness, the total number of punctate hemorrhages in included in tables III and IV.

Table III: Intra muscular punctate hemorrhages in split hog carcasses

		Electrically stunned		Unstunned
		routine method	short interval method	
Number of hogs		385	256	196
Punctate hemorrhages	1st degree	16(4.2%)	12(4.7%)	8(4%)
	2nd degree	13(3.4%)	5(1.9%)	3(1.5%)
	3rd degree	3(0.8%)	0	0

1st degree: 1-2 blood hemorrhages per hog
2nd degree: 3-10 " " " "
3rd degree: Pronounced occurrence (deleterious) of punctate hermorrhages.

Table IV: Intramuscular punctate hemorrhages in cut up hams

		Electrically stunned		Unstunned
		routine method	short interval method	
Number of hams		79	543	485
Number of punctate hermorrhages	1	10 (12.7%)	10 (1.8%)	12 (2.5%)
	2-3	2 (2.5%)	5 (1%)	0
	4-6	2 (2.5%)	3 (0.6%)	1 (0.2%)
	7-10	2 (2.5%)	0	0
	11-15	1 (1.3%)	0	0
	16-21	2 (2.5%)	0	0
	22-28	1 (1.3%)	0	0

In summary, the examinations showed:

In the case of split carcasses, punctate muscle hemorrhages were found more often in hogs stunned electrically by the routine method (incidence 8.3 %) than in unstunned hogs (incidence 5.6 %). In most the hemorrhages were slight and without practical significance. Seriously deleterious punctate hemorrhages occurred only in hogs stunned electrically by the routine method (incidence 0.8 %).

In the case of cut up hams, deleterious punctate hemorrhages (more than 10 per ham) occurred only in hogs stunned electrically by the routine method (incidence 5.1 %).

When electric stunning was accomplished by the altered technique (short interval, that is, at the most 5 seconds between the removal of the tongs and sticking), and there was no real difference in their incidence in electrically stunned and unstunned hogs.

Diffuse Muscle Hemorrhages

In addition to the punctate hemorrhages, so-called diffuse bleedings may occur in the flesh of slaughtered hogs. The diffuse bleedings differ from the punctate hemorrhages in their irregular patchy shape and in that they appear singly in certain characteristic places, for example, on the inner side of hams and in the pelvis. They are large dark bruises from 2 to 5 cm in diameter, sometimes larger. The diffuse bleedings are effusions of blood which occur as the result of severe traumatic tearing or rupture of the tissues. Such insults occur during transport and loading of the animals or during shackling and hoisting. The largest diffuse bleedings are due to tearing of the ligament and joint capsule in the hip joint during hoisting; indeed the femur by which the hog is shackled may sometimes be broken.

Diffuse bleedings are not assumed to have any connection with electrical stunning. Nonetheless the Committee recorded the frequency of occurrence of diffuse bleedings, as shown in tables V and VI.

Table V: Diffuse intramuscular bleedings in split hog carcasses

	Electrically stunned		Unstunned
	routine method	short interval method	
Number of hogs	385	256	196
Diffuse Bleedings: 1st degree	72 (18.7%)	50 (20%)	40 (20%)
Bleedings: 2nd degree	10 (2.6%)	6 (2.3%)	5 (2.5%)

1st degree: diffuse bleedings 2 cm. in extent
2nd degree: " " 5 cm. " "

Table VI: Diffuse intramuscular bleedings in cut up hams

	Electrically stunned		Unstunned
	routine method	short interval method	
Number of hams	79	543	485
1st degree	4 (5.1%)	61 (11%)	59 (12%)
2 x " "	1 (1.3%)	7 (1.3%)	4 (0.8%)
Diffuse 2nd degree	0	8 (1.5%)	1 (0.2%)
Bleedings 2 x " "	0	1 (0.2%)	0

2 x 1st degree: 2 diffuse bleedings 2 cm. in extent
2 x 2nd " : 5 " " 5 cm. " "

In summary: diffuse bleedings occur more often than punctate muscle hemorrhages and with about the same frequency in all groups.

LUNG HEMORRHAGES

The results of the Committee's investigations on this point can be summarized as follows:

Punctate or diffuse hemorrhages in the lungs, varying in severity, were observed in about 25% of the lungs of electrically stunned hogs. The majority of the cases were, however, slight. In the lungs of unstunned hogs, only slight bleedings were found in only a few cases. The change in the electrical stunning technique mentioned above, with the reduced interval between the termination of the stunning and sticking, did not reduce the number of lung bleedings, but rather the frequency seemed to be increased.

However, great importance cannot be attached to lung hemorrhages when the practicability of electric stunning is in question.

The Physiological Basis for the Occurence of Muscle and Lung Hemorrhages in Electric Stunning

With respect to so-called diffuse bleedings, there is hardly any doubt that they are due to trauma during transport and slaughtering and that electric stunning is irrelevant. With regard to lung and punctate hemorrhages, these must be considered to be due to rupture of the capillary walls, probably as a result of increased venous or intracapillary (and arterial) pressure. Blood circulatory changes caused by electric stunning must therefore be considered of decisive importance in their causation. Only a few experiments have been carried out on hogs with regard to this special problem, but experiments on other animals should clarify the problem sufficiently.

The current flow through the hog's brain stimulates its deeper as well as its superficial centers, including the blood pressure regulating center in the medulla oblongata. The first effect is to reduce cardiac output by stimulation of the inhibitory nerves to the heart. Cardiac output is further impaired by the pronounced increase in intrathoracic pressure caused by the tonic contration (see page 6) in abdominal and chest muscles. Furthermore, the generalized tonic convulsions express the blood from the muscle capillaries and increase the volume of blood in the large veins near the heart. This venous congestion, combined with the decreased cardiac output, results in an increase in venous pressure to more than double the

normal. Similarly the arterial blood pressure increases temporarily to about double the normal. The increase in arterial pressure is due to contraction of the small arteries (arterioles) to increase the resistance to flow in the arterial system. Due to the reduction in cardiac output, this increase in arterial blood pressure is not seen until after about 10 seconds have passed.

Since the capillaries of the muscles are occluded during the tonic phase, rupture of their walls and bleeding is unlikely during that period. In the clonic phase, on the other hand, when the muscles alternately contract and relax, the blood can pass through certain areas of the capillary bed. Since the pressure in the venous capillaries has risen to more than twice the normal level, the average pressure in a capillary must increase to more than twice the normal if blood is to pass through. Since the arterial blood pressure has also risen, the intracapillary pressure in the muscles must be assumed to increase considerably during the first part of the clonic phase. The likelihood for rupture of the capillary walls is therefore greatly increased. It should be pointed out, however, that electric stunning does not necessarily lead to rupture, but that there must be a predisposing element in certain hogs (unusually weak capillary walls) since these hemorrhages occur so infrequently.

The changes in blood circulation mentioned above also account sufficiently for the fact that lung hemorrhages are seen more frequently in electrically stunned than in unstunned hogs. Furthermore the increase in pulmonary venous pressure occurs at the beginning of electric stunning, contrary to the case in the muscles, where the capillaries are not occluded until the tonic phase; such a temporary "protective" mechanism is not found in the lungs. In such a richly vascular organ as the lung, the chances for rupture of the capillaries at one or another place is much greater than in muscle, and the expected frequency of hemorrhages in the lungs is correspondingly higher.

The physiological considerations are thus in agreement with the experimental results that multiple punctate hemorrhages can be provented by use of the "short interval" method in electric stunning. As mentioned above, the muscles are bloodless in the tonic phase, and the altered circulatory conditions do not cause substantially increased intracapillary pressure until the beginning of the clonic phase. In the "short interval" method, the animal is stuck before it enters the clonic phase, and the pressure increase which otherwise would have overloaded the walls of the capillaries, has not yet become manifest.

The Degree of Exsanguination and Muscle Rigidity.

Histological investigations carried out at the Pathological-Anatomical Institute of the University of Copenhagen (Prosector Teilum) of muscle samples from 15 unstunned and 15 stunned hogs indicated no difference in the completeness of exsanguination in that no expansion or congestion of the capillary bed was found either in unstunned or stunned hogs.

The degree of rigidity is mainly dependent on a series of factors (the prior treatment of the animal, handling during transport and before slaughter, etc.) which are irrelevant to electric stunning. In addition, during its experiments the Committee heard no complaints from slaughter-house personnel regarding muscle rigidity and this question has therefore been of subordinate importance.

THE INFLUENCE OF ELECTRIC STUNNING ON THE pH OF THE MEAT.

The question as to the influence of electric stunning on the pH and the perishability of the meat has been of great interest to the meat industry. On the basis of pH measurements made by the Danish Meat Research Institute and investigations on the perishability of meat made by the Danish Bacon Control - or according to lines laid down by it - it has been claimed that electric stunning increases the perishability of the meat.

It is well-known that there is some connection between the durability of meat and its acidity (pH) in that an initially high pH often supports the growth of certain bacteria, and in that decomposition is accompanied by an increase in the pH of the meat. In attempting to determine the limits of pH which must be assumed to indicate increased perishability, due consideration must be given to the significant variation in pH from animal to animal, both in stunned and in unstunned hogs.

Measurements made during past years at the Danish Meat Research Institute in Roskilde were said to show that the meat of electrically stunned hogs (routine method) has a higher pH (0.2 pH units) than meat from unstunned hogs. On this basis it was concluded that the durability of meat from electrically stunned hogs was inferior to that from unstunned hogs. The experiments were made by inserting a spear glass electrode directly into the muscle.

The Committee made a number of preliminary measurements using the same procedure. Ten measurements were made at different sites in each m. quadriceps femoris examined to obtain an average pH. Split carcasses of

7 stunned and 7 unstunned hogs were used about 24 hours after sticking. All 140 measurements were made on the same day and the results are given in Appendix 1 (page 23). Within one and the same muscle widely varying pH values were found; the greatest difference was 1.4 pH units. The average pH for the various hogs varied greatly; this holds true for unstunned as well as stunned hogs, the standard deviation for stunned animals being 0,11 pH units, for unstunned animals 0,24 pH units. The average pH for unstunned hogs (70 measurements) was 5.85 $\pm$ 0.07 and for stunned hogs (70 measurements) it was 5.93 $\pm$ 0.07. The difference of 0.08 pH units has accordingly a mean error of 0.10 pH units.

It can furthermore be calculated from the table that the standard deviation of a single pH measurement with a spear electrode is, on the average, 0.2 pH units for both stunned and unstunned hogs.

Another way to determine the final pH of the meat is the so-called macerate method. The meat is finely macerated and the pH measured after the glycogen in the muscle has been broken down completely to lactic acid (glycolysis).

The Committee made two series of experiments using the macerate method. In a preliminary study the perishability of tenderloins (m. iliopsoas) was tested chemically (see page 19). The series included 32 samples from unstunned and 33 samples from electrically stunned hogs (short interval method). The measurements showed an average pH of 5.61 $\pm$ 0.04 for stunned hogs and 5.50 $\pm$ 0.02 for unstunned hogs (see Appendix 2).

However, the results of this experiment cannot be considered conclusive in an evaluation of the influence of electric stunning on pH of the meat: (a) the number of measurements in each of the two groups was small (32 and 33). (b) the experiment was made under conditions where one did not aim at the precision which later proved to be necessary. (c) pH measurements were made between 0 and 2 hours after maceration and no successive measurements were made to insure that a stationary pH was achieved by this technique.

The Committee therefore made another series of measurements: Since the problem of perishability is more actual in the case of hams than of tenderloins, this investigation was made on the m. gracilis of 473 hogs, of which 224 were unstunned and 249 stunned (short interval method). In order to have as uniform conditions as possible, the experiment was carried out on a slaughtering lot from one day. The slaughtered hogs were hung in the chilling room of the slaughterhouse at 4 ^{o}C. overnight and muscle

samples containing no fat tissue were taken from the same area in each muscle 20 hours after slaughter. Each sample was macerated immediately after it was cut. The macerates were stored for 6 hours at 20 °C., and the pH was then measured. The pH measurements were doubly checked since each sample was divided into two and measured simultaneously by two persons who observed all of the rules necessary to achieve as precise measurements as possbile. If the two measurements differed by more than 0.04 pH units, they were rejected and the pH of the divided sample redetermined. The results of this investigation of pH in the macerate were as follows:

(a) electrically stunned hogs (short interval method)
Average value for 249 macerates, pH - 5.47
Standard deviation: 0.14 pH units
Standard error of the mean 0.01 pH units.

(b) unstunned hogs
Average value for 224 macerates, pH 0 5.48
Standard deviation: 0.13 pH units
Standard error of the mean 0.01 pH units.

The difference between the two average values is 0.01 pH units and has a standard deviation of 0.013 pH units. Consequently, there is no statistically significant difference in average pH of muscles from electrically stunned and unstunned hogs.

The experiment thus gave the unequivocal result that the pH of macerates of hams (m. gracilis) from unstunned and stunned hogs was the same. It should furthermore be mentioned that in almost all cases the meat samples were divided into two and the part that was not used in the main experiment was placed in cold storage at the Bacteriological Laboratory of the Royal Agricultural College. Here the samples were macerated two days after slaughter in groups of 20 pieces and the pH of the macerates was again measured. The results showed that the average value of the pH for unstunned hogs was 5.46 and for stunned 5.45. Thus the pH of the macerates did not change during storage for an additional day. For a more detailed description of the experiment refer to Appendices 3 and 4.

With pH (measured by the macerate method) as an indication of perishability, no difference in the perishability of ham (m. gracilis) of stunned and of unstunned hogs could be demonstrated in the present series of experiments.

THE INFLUENCE OF ELECTRIC STUNNING ON THE PERISHABILITY OF MEAT.

Two series of experiments were made to evaluate the perishability of fresh meat from electrically stunned and unstunned hogs. In the one an organoleptic evaluation was made of the freshness of the meat, that is, an evaluation on the basis of appearance and odor. In the other series ammonia which increases in amount during spoilage, was determined as the sum of volatile nitrogen compounds liberated by distillation with magnesia.

Organoleptic Tests for Spoilage of Fresh Hog Carcasses.

Forty pork sides, 20 from unstunned and 20 from electrically stunned hogs (short interval method, slaughtered under observation at the slaughterhouse in Sorø) were taken the day after slaughtering to a cold storage room at A/S Cold Stores, Islands Brygge. The cold storage room was maintained at + 10 to 12 °C. with a relative air humidity of about 93 %.

After 2, 4, 5, and 6'days' storage under these conditions, the appearance and odor of the pork were evaluated by the Committee and independently by an inspector from the Danish Bacon Control. The latter classified the meat according to the point scale from 10 (best) to 0 (poorest) which is used by the Bacon Control. In 6 cases double evaluations were made and differences of up to 3 points for the same hog appeared. The Committee itself used an ordinary description of the condition (odor, color, slime formation) along the lines used by veterinary meat inspectors in evaluating the freshness of a carcass. The average results of the evaluations are given in the summary below:

1: evaluation after 2 days' storage
All pork sides fresh.

2: evaluation after 4 days' storage
a: The Bacon Control's evaluation:
Unstunned 7 points
Electrically stunned 7 points
b: The Committee's evaluation:
Unstunned 15 without bad marks 5 with bad marks
Electrically stunned 16 " " " 4 " " "

3: evaluation after 5 days' storage

a: The Bacon Control's evaluation

Unstunned	5 points
Electrically stunned	5 points

b: The Committee's evaluation:

all sides show signs of beginning superficial spoilage, more noticeable in the neck and along the breastbone. Condition very uniform. The sides which gave the poorest impression with regard to odor and slime formation were selected jointly. Of the 8 selected, 4 were unstunned and 4 electrically stunned.

4: evaluation after 6 days' storage

superficial spoilage more advanced, the pork still usable, however, after trimming. All of the sides were laid up beside one another and sorted according to freshnesss into three groups:

	Unstunned	Electrically stunned
1: poorest group	2	3
2: not so poor group	7	6
3: best group	11	11

The difference between groups 2 and 3 is doubtful, and since the experiment approached the point where continuation would wipe out all differences in freshness, the experiment was discontinued. Deep spoilage was not found in any of the sides examined.

The experiment shows that, under the deliberately chosen unfavorable storage conditions, no difference could be demonstrated with regard to the durability of the fresh pork in the two groups of unstunned and electrically stunned hogs, by either the Committee's or the Bacon Control's evaluation.

Evaluation of the perishability of the meat through determination of "ammonia" formation at constant temperature.

Evaluation of the keeping quality of the meat by organoleptic tests is burdened with the faults connected with any method which is based on a subjective estimation. Therefore, it was considered essential that the direct organoleptic investigation be supplemented by a method which was based on objective criteria. Such a method is the determination of the amount of "ammonia" which, under well-defined conditions, develops

with time in the meat. "Ammonia" nitrogen originates from the breakdown of the proteins of the meat as a result of spoilage, and the quantity of "ammonia" nitrogen represents therefore a measure of the degree of spoilage of the meat.

The meat (in this series of experiments tenderloins) was taken asceptically from the slaughtered hogs immediately after slaughter; all of the subsequent handling of the meat was done under adequate asceptic conditions. The meat was ground and stored at + 10 °C. At the time the meat was ground the first measurements were made: a determination of the dry matter and "ammonia" and pH determinations. During the subsequent storage of the meat, "ammonia" and pH were measured at 6 and 8 days and thereafter at intervals depending on the condition of the meat. In all, 65 tenderloins were investigated, some from stunned ("short interval") and some from unstunned hogs.

Approximately the first half of the material was required to perfect the technique and during this time it was observed that the changes in the meat were of three types, presumably determined by the type of infecting microorganism. The types of changes can be described briefly as follows:

a: surface light red, glistening, later darker, slimy and very damp. Relatively quick development of evil-smelling substances; increase in "ammonia" formation and in pH.

b: surface red, dry; only slight development of evil-smelling substances; slight increase in "ammonia" and in pH after about 8 days.

c: surface grey, dry to slightly damp. No development of evil-smelling substances; pH constant or decreasing and increasing only after a long time; "ammonia" increases very slowly, even after a long time.

Technically it was only possible to carry out the investigations on the samples, in all 14, which belong to category a; of these, 7 came from stunned and 7 from unstunned hogs. At the time of grinding of the meat, the "ammonia" content was approximately 0.07 % of the dry weight of the meat and remained approximately constant during the first days of storage. After about 7 - 9 days, a "critical" time, "ammonia" formation suddenly increased sharply, so that in the course of the following 2 days it amounted to approximately ten times the inital value. At the "critical" time the meat started to smell bad. The pH increased during the following days up to about 8.

A well-defined objective measurements for the time the meat remained in a satisfactory state of preservation was the time elapsed from grinding to the "critical" time. For the 7 samples from unstunned hogs, the average time was 179 $\pm$ 3 hours and from the 7 samples from stunned hogs it was 168 $\pm$ 9 hours. Thus the Committee did not demonstrate any difference in the perishability of meat from stunned and unstunned hogs.

CONCLUSIONS.

(1) The Committee has no doubt that the slaughterhouses have had a problem with regard to muscle hemorrhages consequent to electric stunning. Deleterious punctate hemorrhages also appeared in the Committee's material; punctate hemorrhages were found in 3 of 385 split carcasses of hogs stunned electrically by the method used heretofore, and deleterious hemorrhages were found in 4 af 79 cut up hams from hogs stunned by the same technique. In no instance were such hemorrhages observed in the meat of unstunned hogs.

(2) The Committee's investigations have shown that deleterious punctate hemorrhages in the muscles can be avoided if the time interval between the interruption of current flow and sticking is reduced substantially, from about 50 seconds to about 5 seconds. It should be pointed out that the success of this new electrical stunning technique is dependent on its being carried out precisely as described.

(3) It must be assumed that the electrically stunned hog is unconscious during the whole period from the beginning of current flow until it is stuck.

(4) The diffuse hemorrhages appear equally often whether the animal is stunned or not. This is true both when stunning was carried out by the routine method and when the now recommended "short interval" method was used.

(5) The stunning tongs used at present should be replaced by tongs having a frame of insulating material. The stunning apparatus used hitherto can, in the Committee's opinion, hold some risk for the user under certain conditions. The Committee suggests that the attention of the Electricity Commission be called to the results of the Committee's investigations of the apparatus used heretofore so that the question can be taken up for renewed consideration.

(6) The Committee's investigations with the use of the short interval method have given the unequivocal result that the pH in macerate of m. gracilis from hams from unstunned and stunned hogs was the same. Using pH as an indication of perishability the Committee concludes that, in the present series of experiments, no difference could be demonstrated in the perishability of meat from stunned and unstunned hogs.

(7) The Committee did not find any difference by organoleptic and chemical investigations in the perishability of meat from stunned and unstunned hogs.

Appendix 1.

pH Measurements with a Glass Electrode (Spear Electrode) in the m. quadriceps femoris of Hogs 24 hours after Slaughter (Made in Sorø on November 10 and 11, 1955).

Measurement no.	Hog no.	91	94	139	174	161	93	140	195	177	87	108	106	144	100
				+		+		+				+	+	+	+
1		6,53	5,68	6,00	5,88	5,89	5,80	5,84	6,25	6,06	5,52	5,70	6,05	5,90	5,98
2		6,50	5,68	6,05	5,66	5,80	5,68	5,83	5,62	5,41	5,61	5,88	6,90	6,18	5,90
3		6,09	5,68	5,88	5,51	5,79	5,67	5,83	5,87	5,91	5,75	5,99	6,15	6,19	5,98
4		6,50	5,48	5,84	5,50	5,62	5,58	5,70	5,70	6,02	5,82	6,06	5,48	5,68	5,98
5		6,40	5,70	5,90	5,41	5,67	5,63	5,98	5,58	5,70	5,98	6,08	6,20	5,75	6,09
6		6,66	6,19	5,90	5,55	5,71	5,81	5,90	5,70	5,90	5,62	5,76	5,79	5,70	5,94
7		6,19	5,88	5,81	5,56	5,82	5,69	5,83	5,78	6,15	5,80	5,90	6,08	5,68	6,00
8		6,51	5,67	5,80	5,52	5,65	5,75	5,72	6,19	5,90	5,89	5,90	6,03	5,71	6,08
9		6,41	5,62	6,03	5,60	5,69	5,70	6,13	6,30	6,00	5,89	6,00	6,00	5,79	6,02
10		6,60	5,80	5,52	5,69	5,82	5,62	7,10	5,72	5,80	5,58	5,80	6,03	6,26	6,20
Average:		6,44	5,74	5,87	5,59	5,75	5,69	5,99	5,87	5,89	5,75	5,91	6,07	5,88	6,02

Note: Numbers marked with + indicate stunned hogs (routine method)

Appendix 2.

pH measurements in macerates from Tenderloins.

Electrically Stunned (Short Interval Method)

5.52	5.83	5.46
5.40	5.50	5.43
5.57	5.48	5.93
6.01	5.50	5.39
5.52	6.11	5.75
5.28	5.52	5.42
5.45	5.53	5.98
5.59	6.06	5.35
5.40	5.58	5.25
5.51	5.63	6.24
5.63	5.77	5.62

Unstunned Hogs

5.58	5.41	5.70
5.33	5.55	5.60
5.41	5.62	5.47
5.39	5.38	5.43
5.53	5.62	5.46
5.41	5.67	5.43
5.50	5.66	5.38
5.50	5.23	5.30
5.53	5.63	5.53
5.69	5.55	5.58
5.56	5.44	

Appendix 3.

Experiment to determine the Time Required for a Meat Macerate stored at 20 °C. to attain a stable pH (10 April 1956). Maceration was done immediately after slaughter.

Hours	0*)	1/2	1	2	3	4	6	7
Quadriceps	6.40	6,27	6.19	5.90	5.82	5,75	5.75	5.75
Adductor 1	6.28	6.10	6.05	5.75	5.75	5.65	5.65	5.65
" 2	6.20	5.89	5.68	5.60	5.60	5.60	5.60	5.62

*) 2 hours after shooting.

Appendix 4.

Distribution of pH values in Muscle Macerates from Electrically Stunned and Unstunned Hogs. (Experiment carried out at the Sorø Cooperative Slaughterhouse, April 24, 1956).

In April 1956 the Committee decided to undertake a new experiment concerning the question of the influence of electrical stunning on the pH of the meat of slaughtered hogs.

As a result of the fact that the direct pH measurements (with a spear shaped glass electrode inserted in the muscle) had shown great variation within the same muscle, it was considered necessary to use muscle macerates for pH evaluations. From previous experience concerning the spread of the measurements, it could be estimated that it would require at least 160 measurements within each group to show a difference in pH of the order of 0.1.

The Danish Meat Research Institute pointed out that the measurements should be made on split carcasses after they had been in cold storage for a day (at a temperature of about 2 °C). To obtain the greatest possible uniformity of the material, it was decided to carry out the experiment on hogs slaughtered on the same day. The hogs were slaughtered under proper control on Monday, April 23, 1956 and the pH measured the next day, Thueday, April 24, 1956. To carry out such an extensive experiment on one day, it was necessary to employ a considerable number of participants (in all 18) in the experiment. Prior to the experiment a detailed plan was

worked out and given to each of the participants so that all were familiar with the procedure. In addition, certain preliminary measurements were made.

Procedure:

1. Slaughtering Day (Monday, April 23).

The hogs were slaughtered with and without prior electric stunning in groups of 20 at a time. The hogs were marked on the hams with tattooing tongs (0 for electrically stunned and 1 for unstunned) while in the pen prior to sticking. In order to make sure that all of the hogs were properly marked and to make it easy for the stunning personnel to find out which treatment each hog should be given, every hog was painted with a color at the same time that it was tattooed (red-electric stunning; green-no stunning).

An observer familiar with the correct procedure for the "short interval" method was placed in the sticking pen. All of the hogs which, for some reason or other were not stunned according to the rules were marked by the sticker by a cut in the ear and excluded. Hogs which were thought to be sick on arrival in the sticking pen were also marked with an ear slit. When the carcasses were weighed, all those having a cut on one ear were sorted out, along with those found to be faulty by veterinary inspection. All these hogs were placed in a special place in the chilling room so that they would not be included in the material the next day.

2. Measuring Day (Thuesday, April 24, 1956).

The experiment began at 6 a.m. The meat samples were cut out in the slaughterhouse at the place where the pork sides are laid on the trimming belt. The samples, about 30 g of muscle, were cut from m. gracilis in the ham by one of the members of the Committee. The latter had an assistant to find the tattoo markings (0 or 1) on the hogs. The sample was, as far as possible, taken from the same place in the muscle and any fatty tissue was avoided. Muscles with diffuse bleeding were not included. The piece cut out was laid on a piece of imitation parchment paper 15 x 15 cm on which the tattooing mark was written. The meat samples were handled as follows: Every sample was trimmed so that it weighed approximately 20 gm. The remaining part was wrapped and put aside for later use. The piece weighing 20 gm. was cut up into

strips a couple of mm thick, weighed on a scale, placed with 1 1/2 times its weight of distilled water in a Waring blender and macerated for 1 1/2 min. It had been ascertained in advance that complete homogenization of the meat was possible within this time and that the treatment in the blender did not cause any noteworthy increase in the temperature of the macerate. When maceration was completed, the homogenized meat sample was emptied into a 100 ml beaker. This part of the experiment ran from 6 to 11 a.m. during which time approximately 500 samples were macerated by 12 persons. The finished macerates stood at 20 °C. for at least 6 hours before the pH was measured with glass electrodes and four pH meters (Radiometer pH-M22). The pH meters had been left on over night and were stable at the beginning of the measurements. To guard against possible errors a double determination was made on every sample: Before being measured, the macerate was carefully stirred with a clean spatula, emptied into two measuring beakers and the two samples were measured separately on two pH meters. A common standard buffer solution (5.50) was used to adjust the four pH meters. Records were taken separately for each glass electrode and the code of the macerate (0 og 1), the time of macerating as well as the time of measuring the pH were noted.

In case of deviations between the double determinations of more than 0.04 pH unit the pH meter was checked and adjusted and the measurements repeated. In this way the variation in the parallel tests did not exceed the limits mentioned above except in one case. In this one case where, because of an unexplainable reason, this was not possible, the measurement was discarded. After each measurement the glass electrode was cleaned carefully with distilled water and the KCl in the calomel electrode was renewed. After every tenth measurement all of the pH meters were checked and adjusted even if some of them had already been adjusted within this interval. This part of the experiment began at 12:30 and was completed by about 10:00 p.m. Fourteen persons took part in the experiment and all were thoroughly familiar with the technique.

Results.

The results are tabulated in table 1 and 2; each value is an average of the double determinations. As mentioned above, a deviation of 0.04 pH unit was allowed between the single values of the double determinations. The error of the individual measurement is therefore about 0.02 pH unit. In the tables the measurements are grouped into class intervals of 0.05 pH unit.

In the first column (x) is given the average of each class interval. In the second column is given the number of measurements (nf) which fall within the particular class interval. In treating the material 5.47 was chosen as a suitable arbitrary mean value and the deviations (x) of each class from 5.47 are given in the third column. In the fourth (nfx) and fifth (nfx^2) columns are given the first and second moment of each class interval with regard to x - 5.47. The mean value (m_1), standard deviation (S.D.) and the standard error of the mean ($e(m_1)$) are given below the two tables.

The results were:

I: stunned hogs:

Average value for 249 macerates, pH - 5.466
Standard deviation: 0.136 pH unit
Standard error of the mean: 0.009 pH unit

II: unstunned hogs:

Average value for 224 macerates, pH - 5.478
Standard deviation: 0.133 pH unit
Standard error of the mean: 0.009 pH unit

The difference between the average values is 0.012 pH unit and has a standard deviation of 0.013 pH unit. Hence the two distributions of the pH values of the macerates from unstunned and stunned hogs do not differ significantly from each other with regard to mean value and standard deviation.

In the above calculations the material was grouped into class intervals of 0.05 pH unit. In addition, the mean value and standard deviation were calculated directly since it might be supposed that the grouping could cause small deviations. However, the grouping in the class intervals of 0.05 pH unit did not influence the results, since the calculations without previous grouping give:

(a) stunned hogs: $m_1 = 5.446$, S.D. = 0.0135
(b) unstunned hogs: $m_1 = 5.479$, S.D. = 0.0134

In the final results only two decimals should be used.

The histogram (fig. 1) below shows the frequency distribution of pH in the two groups. Since the maximum degree of uncertainty was 0.02 pH units, it seemed reasonable to use a class interval of 0.1 pH unit (5 x the maximum degree of uncertainty). As to be expected there was no significant difference in the two distributions. In addition, the two distributions have been compared with the normal distribution by plotting the cumulative frequency as a function of pH. This is shown in fig. 2. The course of the two was identical and for pH lower than 5.65 corresponding to about 92 % of the findings, the two distributions are normally spread.

As mentioned above, the samples were divided into two parts before weighing and twenty samples of each group, not macerated for the original pH measurement, were collected and their pH was measured two days after slaughter.

After the addition of 1 1/2 times its weight of distilled water, the large samples were macerated for 1 minute in a Waring blender and kept for 8 - 10 hours at 20 ^{o}C. before the pH was measured. The results are given in table 4 below.

Table 1. UNSTUNNED HOGS

The Distribution of pH values of 224 Macerates from m. gracilis in Slaughtered Hogs. The measurements were made in the macerate after 6 - 9 hours at 20 °C. Class interval - 0.05 pH unit. x mid point of class interval.

	X	nf	x	nfx	nfx^2
	5.17	1	—0.30	—0.30	0.0900
	5.22	6	—0.25	—1.50	0.3750
	5.27	4	—0.20	—0.80	0.1600
	5.32	17	—0.15	—2.55	0.3825
	5.37	35	—0.10	—3.50	0.3500
	5.42	40	—0.05	—2.00	0.1000
→	5.47	29	0.00	0.00	0.0000
	5.52	34	+0.05	+1.70	0.0850
	5.57	16	+0.10	+1.60	0.1600
	5.62	19	+0.15	+2.85	0.4275
	5.67	11	+0.20	+2.20	0.4400
	5.72	6	+0.25	+1.50	0.3750
	5.77	1	+0.30	+0.30	0.0900
	5.82	0	+0.35	0.00	0.0000
	5.87	2	+0.40	+0.80	0.3200
	5.92	2	+0.45	+0.90	0.4050
	5.97	1	+0.50	+0.50	0.2500
		224		+1.70	4.0100

$m'_1 = \Sigma nfx/\Sigma nf = 1.70/224 = 0.00759$

$m_1 = 5.470 + m'_1 = 5.470 + 0.008$

$m'_2 = \Sigma nfx^2/\Sigma nf = 4.01/224 = 0.0179$

$m_2 = m'_2 - (m'_1)^2 = 0.0179 - (0.00759)^2 = 0.0178$

$S.D. = (m_2)^{1/2} = 0.133$

$e(m_1) = S.D./(\Sigma nf)^{1/2} = 0.133/15 = 0.009$

Table 2. STUNNED HOGS

Distribution of pH Values of 249 Macerates from m. gracilis in Hogs. The measurements were made in the macerate after 6 - 9 hours at 20 °C. Class interval 0.05 pH unit. x mid point of class interval.

X	nf	x	nfx	nfx^2
5.17	0	—0.30	0.00	0.0000
5.22	5	—0.25	—1.25	0.3125
5.27	9	—0.20	—1.80	0.3600
5.32	22	—0.15	—3.30	0.4950
5.37	43	—0.10	—4.30	0.4300
5.42	48	—0.05	—2.40	0.1200
→ 5.47	35	0.00	0.00	0.0000
5.52	34	+0.05	+1.70	0.0850
5.57	17	+0.10	+1.70	0.1700
5.62	17	+0.15	+2.55	0.3825
5.67	5	+0.20	+1.00	0.2000
5.72	4	+0.25	+1.00	0.2500
5.77	1	+0.30	+0.30	0.0900
5.82	5	+0.35	+1.75	0.6125
5.87	1	+0.40	+0.40	0.1600
5.92	1	+0.45	+0.45	0.2025
5.97	0	+0.50	0.00	0.0000
6.02	0	+0.55	0.00	0.0000
6.07	2	+0.60	+1.20	0.7200
	249		—1.00	4.5900

$m'_1 = -1.00/249 = -0.00401$

$m_1 = 5.470 - 0.004 = 5.466$

$m'_2 = 4.59/249 = 0.0184$

$m_2 = 0.0184 - (-0.004)^2 = 0.0184$

$S.D. = (0.0184)^{1/2} = 0.136$

$e(m_1) = 0.009$

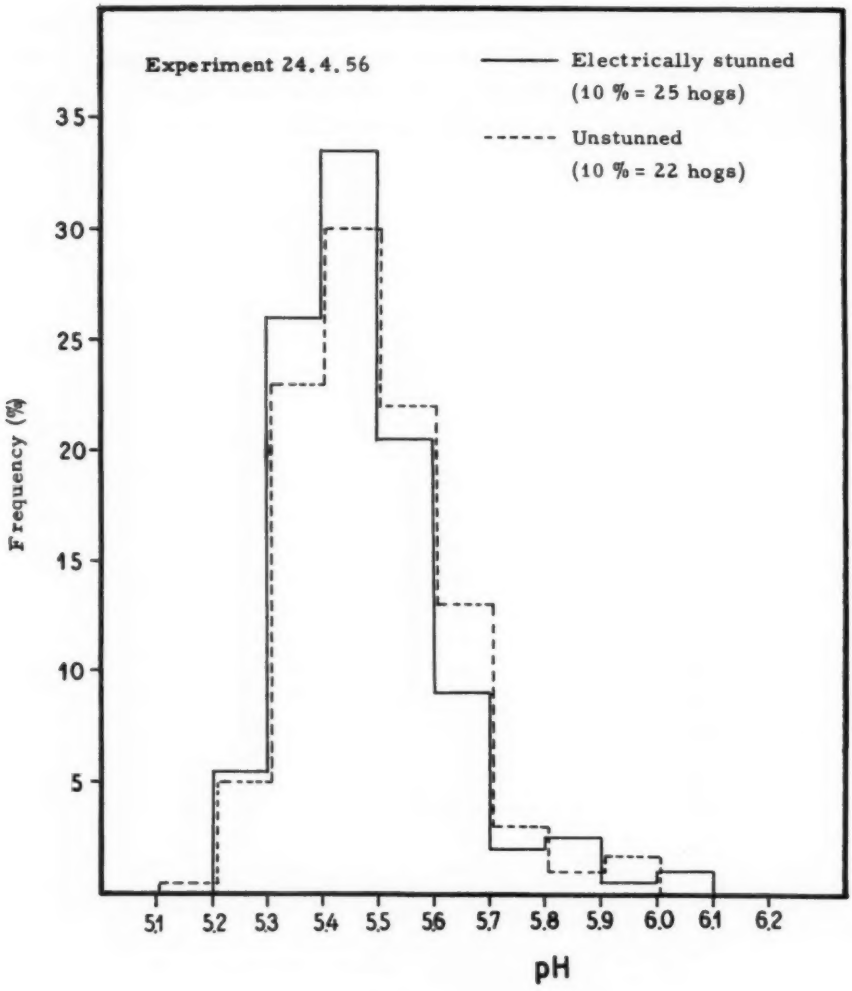


Fig. 1. Histogram of the distribution of pH values of macerates from ham muscle (m. gracilis) from 249 electrically stunned hogs (———) and 224 unstunned hogs (------). The class interval is 0-1 pH unit, that is. 5 x the measurement uncertainty.

Ordinate: Frequency in percent (percentage of the results of the measurements which fall within a given class interval)

Abscissa: pH of the macerates.

Table 3.

The cumulative frequency of pH values of macerates from hog muscle (m. gracilis) from 249 electrically stunned and 224 unstunned hogs.

pH	stunned	unstunned
5.20	0.4	0.9
5.22	1.2	1.8
5.24	2.0	3.1
5.26	2.4	3.1
5.28	4.4	4.9
5.30	7.2	6.7
5.32	11.2	8.9
5.34	14.5	12.5
5.36	18.0	16.5
5.38	26.1	24.1
5.40	38.1	32.6
5.42	46.2	39.7
5.44	51.0	46.0
5.46	54.6	49.0
5.48	59.8	55.8
5.50	67.9	62.1
5.52	74.3	69.6
5.54	78.7	74.1
5.56	80.7	75.9
5.58	84.3	78.7
5.60	88.0	82.6
5.62	91.2	86.2
5.64	92.4	89.7
5.66	92.8	91.1
5.68	94.0	94.2
5.70	94.4	94.6
5.72	96.0	96.4
5.74	96.0	97.3
5.76	96.0	97.3
5.78	96.4	97.3
5.80	97.2	97.8
5.82	98.4	97.8
5.88	98.4	98.2
5.90	98.8	99.1
6.00	99.6	100.0
6.10	100.0	

Table 4.

pH-values of macerates from collective samples. Maceration was made 2 days after slaughter.

pH (unstunned)	pH (stunned)
5.48	5.50
5.52	5.47
5.48	5.40
5.45	5.45
5.40	5.46
5.48	5.40
5.49	5.40
5.36	5.52
5.49	5.41
5.41	5.48
	5.44
Average 5.456	Average 5.448

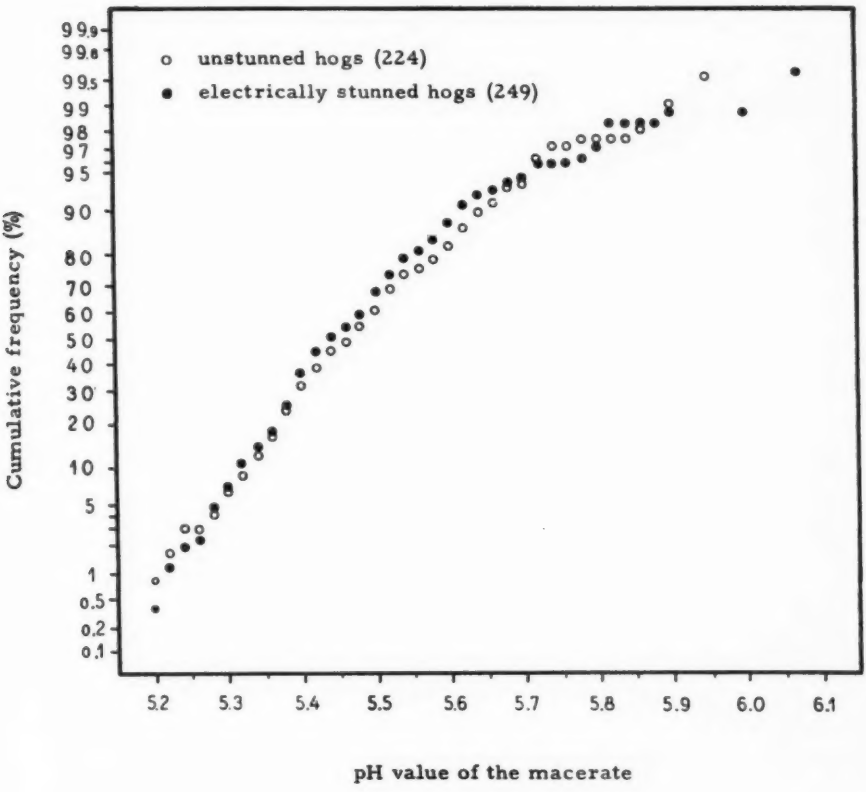


Fig. 2. The cumulative frequency of the pH values of macerates from ham muscle (m. gracilis) from 249 electrically stunned hogs (cccc) and 224 unstunned hogs (oooo).

Ordinate: Cumulative frequency in percent

Abscissa: pH values of the macerates

Note that the scale on the ordinate corresponds to the normal distribution. A cumulative frequency which is normally distributed would, therefore, appear as a straight line in the above diagram.

PF. tryk

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